Western Washington University

Project Completion Report

Puget Sound Shore Erosion Protection Study

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ABSTRACT

Erosion around the marine shoreline of Puget Sound is not as severe as that found along the Pacific Coast, but it does represent a long-term threat and potentially severe financial loss to individual private property owners. Continued erosion forces the property owner to take some kind of action to reduce the loss of his land. Unfortunately, most people understand little about the specific causes of their erosion problems and appropriate cost effective actions. Few sources of information are available to the public. This report explains some of the basic dynamics of shoreline processes in Puget Sound and illustrates some structural and non-structural methods of reducing erosion. In addition, an explanation is given of local, state, and federal agencies that have jurisdiction over the shoreline and permit programs administered by each.

SHORE PROCESSES AND EROSION
ABATEMENT ALTERNATIVES FOR
PUGET SOUND

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INTRODUCTION

Most everyone who has lived near the shoreline of a large water body has at one time seen large structures constructed to protect harbors from waves or to retard the erosion of the shoreline. Where public property is in danger of erosion damage or loss, the U.S. Army Corps of Engineers is empowered by the Congress to take protective measures. However, beach erosion occurs in many areas where the U.S. Army Corps of Engineers is not empowered to act. Foremost among these areas are shorelines under private ownership. Approximately 2075 miles of saltwater shoreline are privately owned in Washington State with about 75 percent of this mileage bordering Puget Sound and Georgia Strait. It is to these property owners that this publication is addressed.

While erosion around the marine shoreline of Puget Sound is not so severe as that found along specific locations of the Pacific coast, it does represent a long term threat and potentially severe financial loss to the property owner. Continued erosion pressures the property owner to take some kind of action to reduce the loss of his land. Unfortunately, most people understand little about the specific causes of their erosion problems and appropriate cost of effective actions. Few sources of information are available to the general public. This publication explains some of the basic dynamics of shoreline processes in Puget Sount and illustrates some structural and non-structural methods of reducing coastal erosion. In addition, an explanation is given of agencies that have jurisdiction over the shoreline and permit programs operated by these agencies.

This guide is not a do-it-yourself blueprint for shore protection, nor a substitute for professional engineering advice and design. When faced with an erosion problem, the information herein will help individuals to make informed decisions about their problem and inform them of available resources.

THE EROSION PROCESS

Shoreline erosion is a natural process caused by the interaction of two systems, the sea and coastal rock formations. The sea is driven by a complicated system of dynamic forces including winds, astronomical stresses, temperature and salinity gradients, plus the earth's rotation which individually or together generate waves, currents and tides. Coastal rock formations present an almost infinite variety of layered and non layered, resistant and non resistant rocks that form banks, bluffs or cliffs along the standard edge of the land. The constant erosion of these coastal rocks and rocks found far inland, whose eroded remains are transported to the sea by rivers, all lead to the buildup of beaches. However, the energy that leads to the natural build up of beaches can also cause its erosion, and it is the latter that most concerns and affects land owners in the coastal zone.

The Sea

Waves

Wind is the generator of waves at sea. The longer and stronger the wind blows and the greater the distance (fetch)* over which it blows, the larger and more powerful the waves will be. Waves are measured by their height, length, and period (fig. 1a). Wave height is the vertical distance from the trough of the wave to its crest. Wave length is the horizontal distance between two successive wave crests; and period is the number of

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* Underlined terms defined in Glossary of Terms

seconds it takes two consecutive wave crests to pass a fixed point. In the relatively protected waters of Puget Sound, wave period is usually less than eight seconds. The higher the wave, relative to its length, the more likely the beach will erode. High steep waves rapidly break upon the shore agitating the beach sediment carrying it both along (parallel) the shore and offshore into deeper water. The net result is a lowering or natural erosion of the beach.

Currents

Currents -- the movement of water from one place to another -- are another force affecting the shoreline. Most important is the longshore current which is generated by waves striking the shoreline at an angle (fig. 1b). The longshore current, in addition to the swash and backwash of waves onto the beach, lead to the movement of beach sediment parallel to the shore known as littoral transport. The prevailing direction of waves relative to the shoreline determine the net direction of the transport. Sediment from eroding bluffs or sediment-laden streams, will be carried along the shore by the littoral current until the current velocity slows sufficiently to allow suspended material to settle. When sediment is scarce the littoral current working with breaking waves will carry existing sediment away from beaches causing erosion. This sediment will eventually be deposited on another beach or carried into deeper water.

Tides

The term tide refers to the periodic rising and falling of water levels caused by the gravitational attraction of the moon and sun. Tides determine the level at which waves hit the beach. They are an important factor in shoreline change when unusually high tides cause coastal flooding or combine

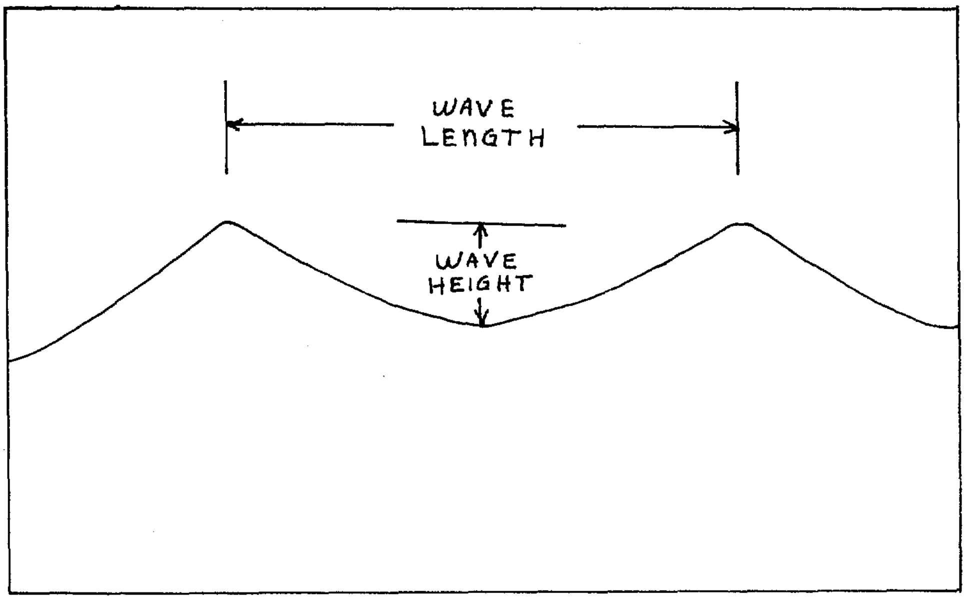


Figure 1a

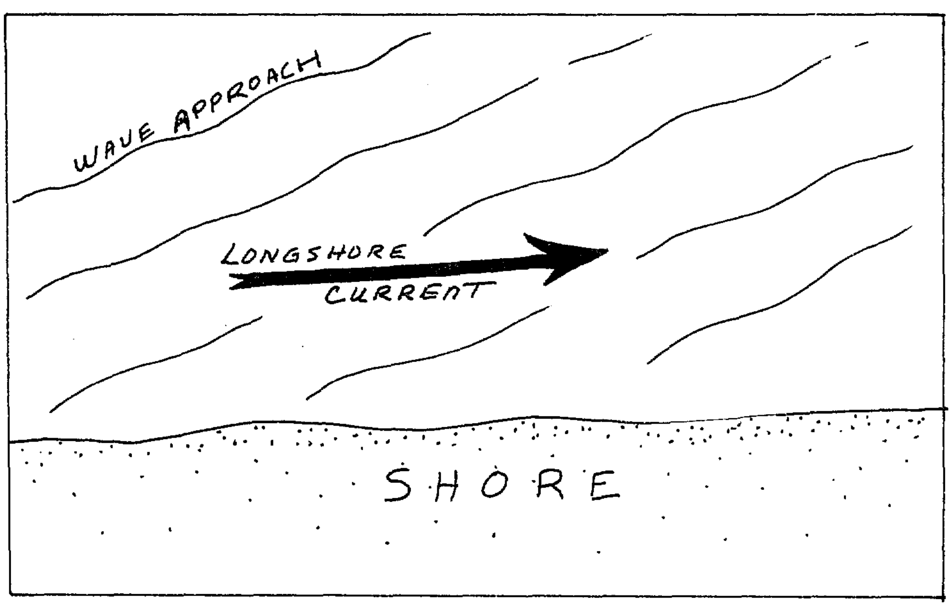


Figure 1b

with storm waves to cause severe beach and bluff erosion and flooding.

Tides can produce currents which become very strong, especially through narrow channels. A strong tidal current can sweep sediments from the littoral zone into or out of bays and channels.

The Land

Beaches

The beach is the first line of defense which protects the land from wave attack. There are two principal features of the beach which make it particularly effective in protecting the land. First, it has a sloping surface which gradually dissipates wave energy as it flows up the slope. Second, it is made of loose unconsolidated sediment allowing water to soak into it and change its slope as waves attack. Any man-made interference with these characteristics will reduce the natural protection of the beach.

Beaches which are exposed to storm-generated waves tend to go through a seasonal change in slope or profile as wave conditions change. Fall and winter storms cause high steep waves to break on shore. These waves remove beach sediment storing it in deeper water in the form of offshore bars. This reduces the amount of sediment on the beach and it becomes lower, narrower and steeper. During the spring and summer, calmer conditions prevail. Waves striking the shore are low gentle waves. These waves carry the sediment from the offshore bars back onto the beach, building it back up and making it wider.

Beach sediment is derived from rivers and from eroding sea cliffs. The beach may be thought of as a river of sand and gravel moving along the shore. If the sediment supply from rivers or bluffs is reduced or stopped, beach erosion is likely to occur. However, if the sediment supply remains stable, the beach will only change with the seasonal change of wave energy, or due to exceptional circumstances.

Nothing substitutes for the work a beach performs. It is a natural defender of the upland from wave attack, the habitat for various types of marine life and land animals and a zone of high recreational value. Every attempt should be made to preserve it in its natural state.

Shore Bluffs

Rimming most of the beaches of Puget Sound are steep shore bluffs, some standing as high as 200 feet or more above the beach. These bluffs are mainly composed of clays, silts, sands, gravels, and boulders laid down during the glacial periods thousands of years ago. Beaches primarily are created from the erosion of these uplands. Sands and gravels fall onto the beach where they become part of the loose sediment until they are carried away by littoral currents. Thus, erosion of sea bluffs is a necessary process for natural beach maintenance. However, not only waves cause bluff erosion. Wind, rain, groundwater, and frost also play an important role in loosening and removing material and bringing it to the beach. The intensity and importance of each varies with the degree of exposure of the bluff, the material it is composed of and other topographic and geologic characteristics. Many landslides are caused where impermeable clay layers underlie more permeable surface soils or glacial strata. After long periods of rainfall, groundwater is unable to penetrate through the silt or clay layer and begins to move laterally saturating overlying materials causing debris slides or slumps. These conditions often weaken the material cohesion of unconsolidated sediments until they lead to slides and slumps.

Property owners should be aware that shore bluffs do erode, some more rapidly than others and in some instances are very difficult to control by an individual land owner or whole community. View homes should be constructed well back from the edge of the cliff to reduce the potential threat of destruction.

EROSION PROTECTION TECHNIQUES

Beaches are dynamic ribbons of sediment that rim most of our uplands. They erode, accrete and are subject to long term changes of shape and volume. Beach processes and responses should be recognized and disturbed as little as possible by man. Yet, be design or ignorance man often disturbs the natural processes at the sea-land interface. Ill-advised intrusion may well lead to new or increased erosion and induce or accelerate the threat of property destruction. The purpose of this section is to briefly illustrate some of the techniques that may be used under optimum circumstances to reduce the erosional threat to personal property. However, in some circumstances, the most prudent action is to do nothing.

Beaches are a resiliant and natural form of protection for the land, however the land is also the source of beach sediment! Thus erosion and accretion are natural processes that continue along our shorelines. Only where the works of man are threatened near an eroding shore may these processes develop into a hazard. Once established along a shoreline, man finds himself in a position of having to consider additional investments to protect his developments. Measures designed to protect property from erosion hazards fall into two general categories: (1) non-structural and (2) structural. Non-structural techniques are always preferable. Furthermore, if the erosion problem impacts neighboring properties, it is wise to develop a coordinated effort toward erosion control. Cooperation will help to reduce costs for professional services and materials as well as prevent the use of a multiplicity of control measures.

Non-Structural Techniques

Construction Setback. The safest measure is to build well back from the active shore zone or bluff edge. This will allow natural processed to operate without the interference from or threat to the property owner. It is difficult to provide a "rule of thumb" setback line that would apply everywhere. Must Puget Sound cities and counties have minimum shoreline construction setback limits established. These must be consulted prior to construction. However, most setback lines are minimum standards and may not be enough to prevent a further erosion threat. Before considering building, it might be wise to ask neighbors about existing erosion problems, or to consult an engineer or geologist or local government staff for advice.

Most people purchase existing structures and have no say regarding the original sitting decision. If erosion presents a hazard, it would be worthwhile to investigate the costs of moving the structure farther back from the beach or cliff edge. Many times such action compares favorably in cost to the construction of a bulkhead or similar structure, which might have a rather short life span.

Vegetation. There is little information available on the potential use of vegetation to help abate shore erosion. While most vegetation is generally unable to withstand direct wave attack, it can be successfully used with other measures to help stabilize beaches or shore bluff slopes. The rooting and ground coverage provided by various plant species help to reduce the erosive effects of rain, running water and frost. Mature upright tree stands reaching the water's edge are an indication that for a period of perhaps several decades or longer beach recession was low or non existant.

Great care should be taken not to disturb existing vegetation on a shore bluff. The existing vegetation is adapted to a particular environment and plays an important role in the overall stability of the slope. If growing vegetation must be cleared, it is wise to have roots embedded within the soil for stability. A local nursery operator or extension agent should be consulted when additional plants are desired to help stabilize a shore bluff.

Beach Nourishment. Beaches are very effective in dissipating wave energy. When maintained, either naturally or artificially, in adequate dimensions, they afford protection for the adjoining backshore. The placing of compatible "borrow" material to help maintain a beach is called beach nourishment. Artificial nourishment directly remedies the basic erosion problem, which is a deficiency of natural sediment. When conditions are suitable for artificial nourishment, long reaches of shore may be protected at a relatively low cost. Furthermore, this method of protection least disrupts natural physical and biological shore processes. The costs, benefits, and long term effectiveness of nourishment should be considered relative to other erosion protection techniques.

Structural Techniques

Any artificial materials placed on a beach to absorb, reflect, or intercept waves or nearshore currents for the purpose of controlling erosion are considered structural techniques for erosion control. Such installations should be employed only as a last resort, for they not only intercept natural shore processes, but are often high cost and have a high probability of failure.

A wide variety of materials and designs are available. Cost may vary significantly among the different types of materials and designs. Steel reinforced concrete is perceived by most people as the ultimate erosion defense. While this may be true in some cases, it is not necessarily true for all erosion problems. The unyielding rigidity of concrete placed upon an ever changing beach with its variety of pressures often spells failure for the structure. A structure that can withstand wave attack and yet yield to changes in the beach profile and pressures from the shore and uplands will likely serve better.

Bulkheads, Seawalls, and Revetments. These structures are all similar in that they are built against or parallel to the shoreline but are used in different situations. They may also be alike in shape and generally constructed of similar materials such as concrete, rip rap, wood, or steel.

Bulkheads serve as retaining walls to shield the upland from wave scour and help hold the land from slumping into the water. They are usually constructed of wood or concrete with footings (base) extending a minimum of two feet below the level of the beach to a minimum of one foot above maximum high tide levels.

Seawalls are specifically designed to withstand the full force of heavy wave attack. They may also serve as retaining walls and in some locations as docking facilities. They are usually constructed of thick steel reinforced concrete with a concave or stairstep face to help rebuff strong wave attack.

Revetments are the lightest of the three structures. They are not intended to retain land or fill, but just to protect the shoreline from waves and currents. They can be constructed of concrete, interlocking blocks, rocks, (rip rap) or boulders.

Groins. Groins are structures placed perpendicular to the shore. Their purpose is to build or maintain beaches by trapping sediment moving in the littoral drift. They may be constructed in various configurations using timber, steel, concrete, or rock. Groins can be classified as high or low, long or short, and fixed or adjustable.

These structures can substantially impact natural beach processes and can have severe consequences. While they trap and build beach sediment for one property, they starve and cause erosion of beaches downdrift. Downdrift property owners are almost forced to take the same action (fig.2). The net result is a domino-like installation of groins along a given length of beach and property owners competing with one another for beach sediment. After careful study along some high energy shoreline environments, groins have been used successfully with a program of beach nourishment. In Puget Sound, the use of groins is seldom justified and should be discouraged as a method of shoreline erosion protection.

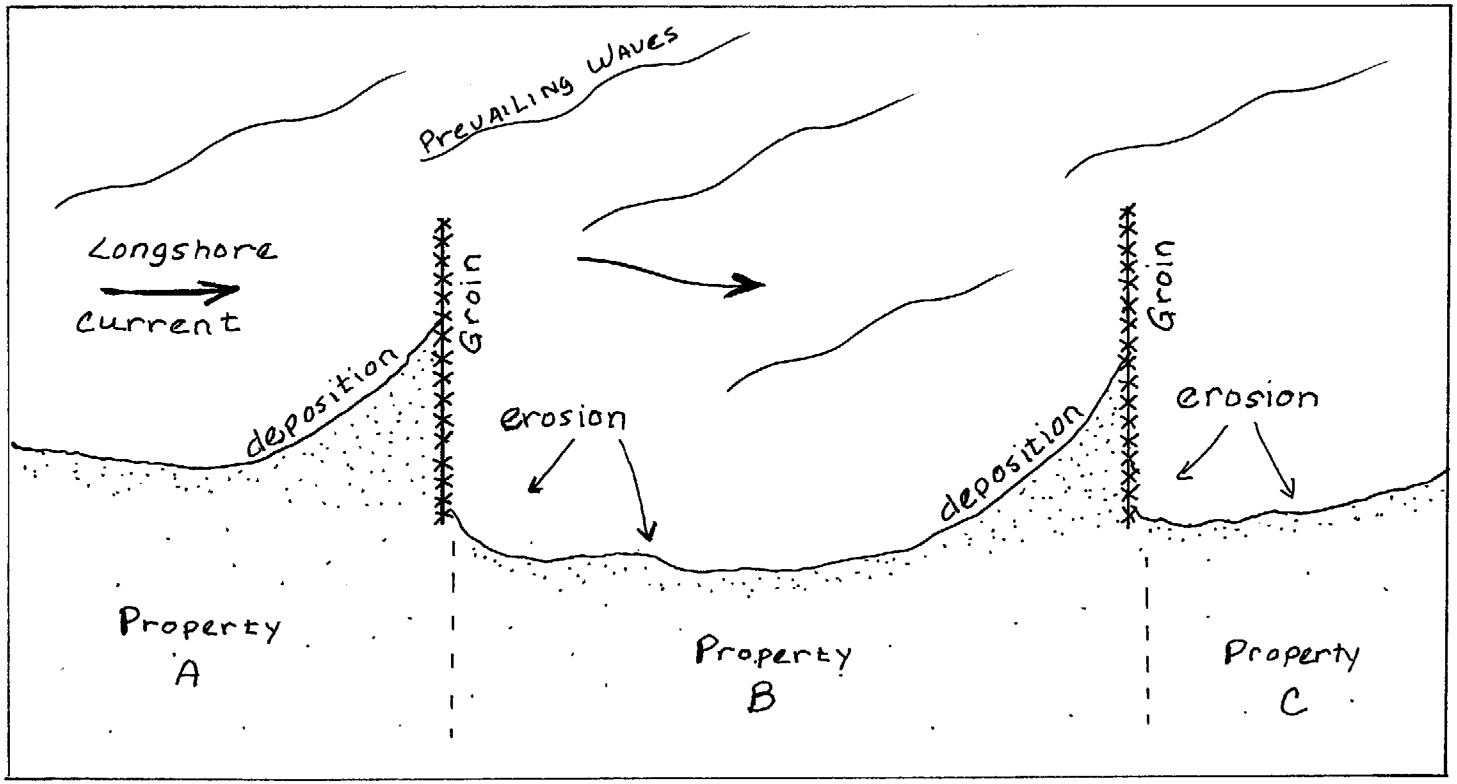

Prevailing Waves
Longshore
Current
Groin
Groin
deposition
deposition
erosion
erosion
Property
A
Property
B
Property
C

Figure 2

CASE EXAMPLES

Many private property owners around Puget Sound are attempting to reduce erosional loss of their shorelands by installing structures of one type or another. Seven such sites were selected for study and reporting. They were selected from around Puget Sound and represent a mix of beaches and structures. These examples are not intended to be used as blueprints, but as illustrations of what has been done and what is planned to reduce erosion. Details of the physical environment, construction designs and materials, prognosis, and possible improvements are given to lead the reader toward a clearer understanding of the problems and prospects of shore erosion abatement.

SHORE PROTECTION STRUCTURES - ANALYSIS OF DESIGN

1. Structure Number: 1

2. Structure Type: Concrete - vertical/recurved bulkhead

3. Location: Birch Bay, Whatcom County

4. Physical Environment

   a. Maximum Wave Heights: Moderate 2-3 feet

   b. Tides: Extreme Tide Range: -4.5 to 12.5
      Mean Higher High Water: 9.5
      Estimated Highest Tide: 12.5

   c. Predominant Littoral Drift Direction: S to N

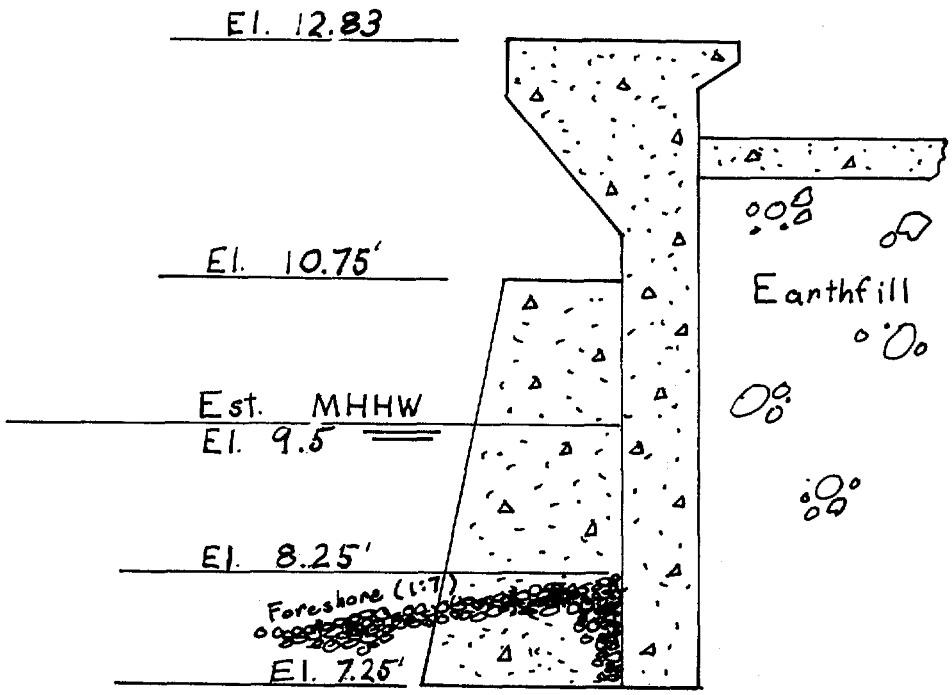
   d. Beach Material: Coarse sand and gravel

5. Coastal Hydraulics

The shore erosion problem at this site may be complicated by two groins which are located several hundred feet to the south. These groins, constructed about 20 years ago, interrupted the northward transport of littoral material, could have contributed to a lowering of the beach profile and erosion in the vicinity of the bulkhead. The bulkhead was built in response to this shore erosion. Since its construction, the beach has lowered about 12 inches leaving another 12 inches of material over the footing. When, or if, these last 12 inches are eroded, exposing the footing, the bulkhead will be in jeopardy of overturning. However, the recent erosion rate at the study site has slowed considerably, according to the bulkhead owner.

6. Construction Details

Cost: $1,000 (self-constructed)



This bulkhead appears adequately strong to resist the level of wave attack experienced at this site. There are no weepholes to provide drainage along the base of the structure, but since the backshore is impervious (concrete patio), none are needed. No tiebacks were incorporated in the bulkhead, a factor which could hasten overturning, should the beach lower more than 12 inches.

7. Prognosis

The remaining useful life of this structure is probably on the order of 20 years. If the beach fronting the bulkhead continues to lower, larger waves will be able to reach the bulkhead without breaking, and the amount of wave overtopping could increase significantly.

8. Possible Improvements

A 3-foot wide blanket of 20-50 pound rock at the toe would help to protect the footing from wave scour and reduce the possibility of bulkhead failure during a severe storm. Periodic placement of a fairly large quantity of sandy gravel at the bulkhead toe would also be a possible alternative should the beach lower more than 6 inches.

SHORE PROTECTION STRUCTURES - ANALYSIS OF DESIGN

1. Structure Number: 2

2. Structure Type: Vertical railroad tie bulkhead

3. Location: Sandy Point, Whatcom County

4. Physical Environment

   a. Maximum Wave Heights: High 5-6 feet

   b. Tides: Extreme Tide Range: -4.5 to 12.5
      Mean Higher High Water 9.5
      Estimated Highest Tide: 12.5

   c. Predominant Littoral Drift Direction: N to S

   d. Beach Material: coarse gravel

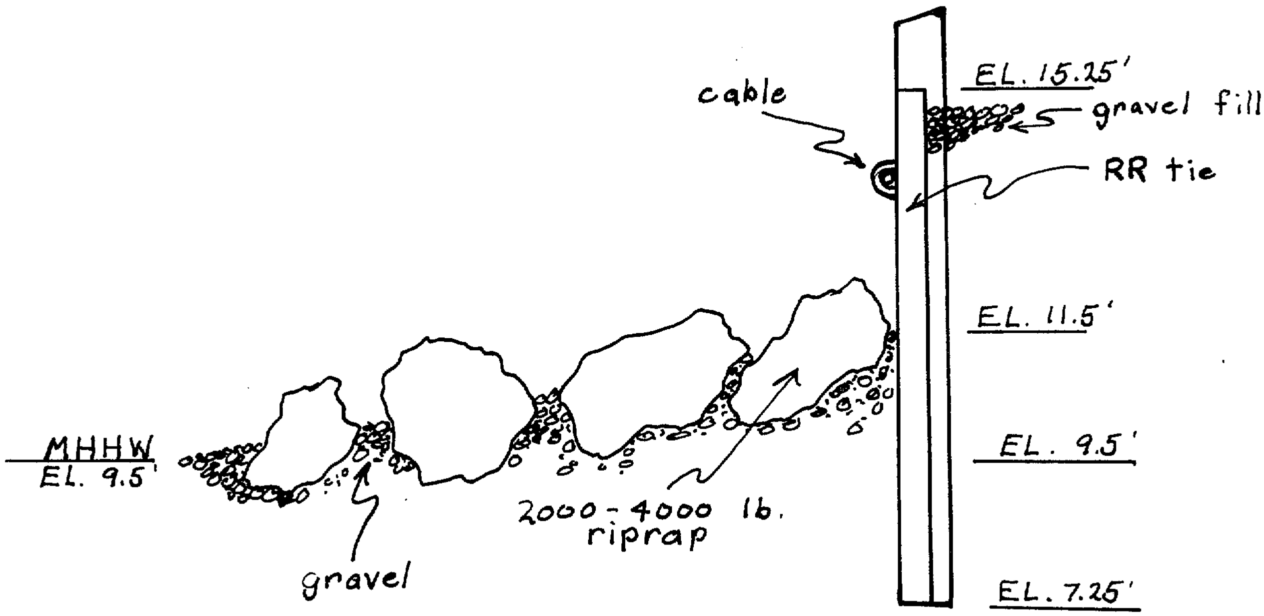
   e. Beach slope: 1:6

5. Coastal Hydraulics

The western portion of Sandy Point is quite exposed to wave action, especially to the 90+ mile fetch up Georgia Strait. Fortunately, strong, sustained northwest winds are rare for the only documented occurrence (29-30 March 1975) caused considerable damage. This storm lasted about 30 hours. Waves driven by 45-knot winds, eroded the beach allowing large logs to be thrown into several beachfront houses. In an attempt to preclude a recurrence of this situation, residents along the exposed portion of the beach constructed bulkheads of varying types, one of which is the site #2 bulkhead.

6. Construction Details

Cost: $4,000



This bulkhead appears adequately strong to resist the normal level of wave attack experienced at this site. The riprap toe protection fronting the structure is adequate in size, but is subsiding because of a lack of proper bedding material. A horizontal cable which connects the railroad ties, probably lends little strength to the structure. Had tiebacks been attached to the cable every several feet, its usefulness would have been much improved. The bulkhead top elevation is sufficient to provide protection from wave overtopping and debris damage, except in the rare event of an exceptionally high tide occurring simultaneously with high winds from the northwest.

7. Prognosis

If the beach fronting this structure remains unchanged, the remaining useful life is estimated to be about 15 years. However, any interruption of the southward transport of beach material to, or along Sandy Point, could result in a lowering of the beach and a corresponding increase in the severity of wave attack at the bulkhead.

8. Possible Improvements

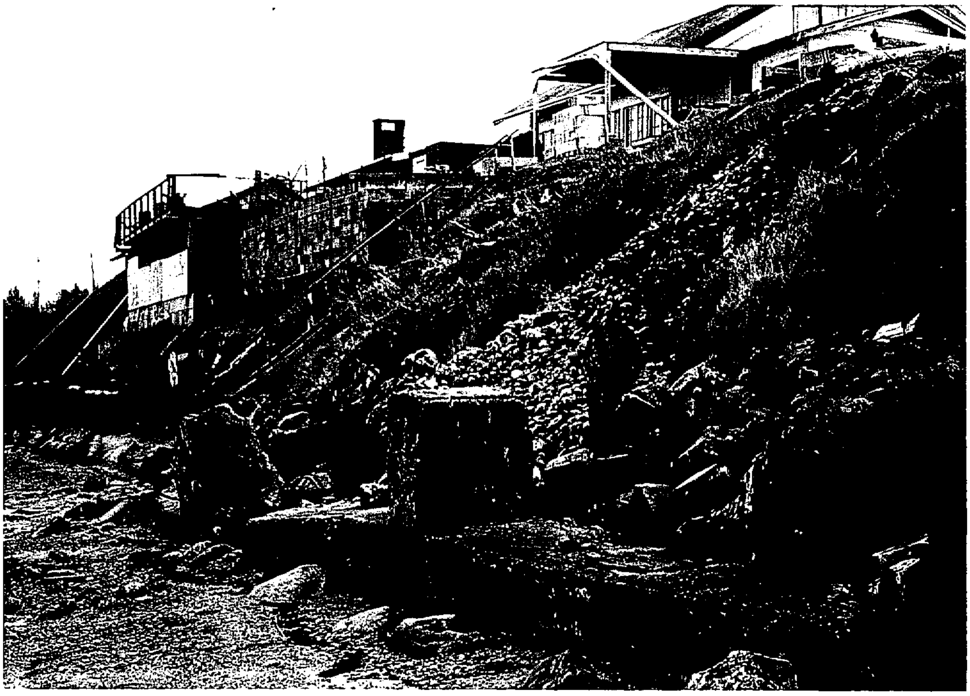
The structure could be improved by removing the existing riprap, placing an 18 inch thick by 8-foot wide blanket of quarry spalls (20-200 pounds) in front of the bulkhead, and then replacing the riprap on the blanket as close to the bulkhead as possible. This procedure would significantly reduct the rate of subsidence of the riprap. However, it should be noted that the recreational and scenic value of the beach has been lessened by the use of riprap.

SHORE PROTECTION STRUCTURES - ANALYSIS OF DESIGN

1. Structure Number: 3

2. Structure Type: Concrete - vertical bulkhead (failed)

3. Location: Samish Island, Skagit County



4. Physical Environment

   a. Maximum Wave Heights

   b. Tides: Maximum Tide Range: -4.5 to 11.0
      Mean Higher High Water: 8.3
      Estimated Highest Tide: 11.0

   c. Predominant Littoral Drift Direction: NW to SE

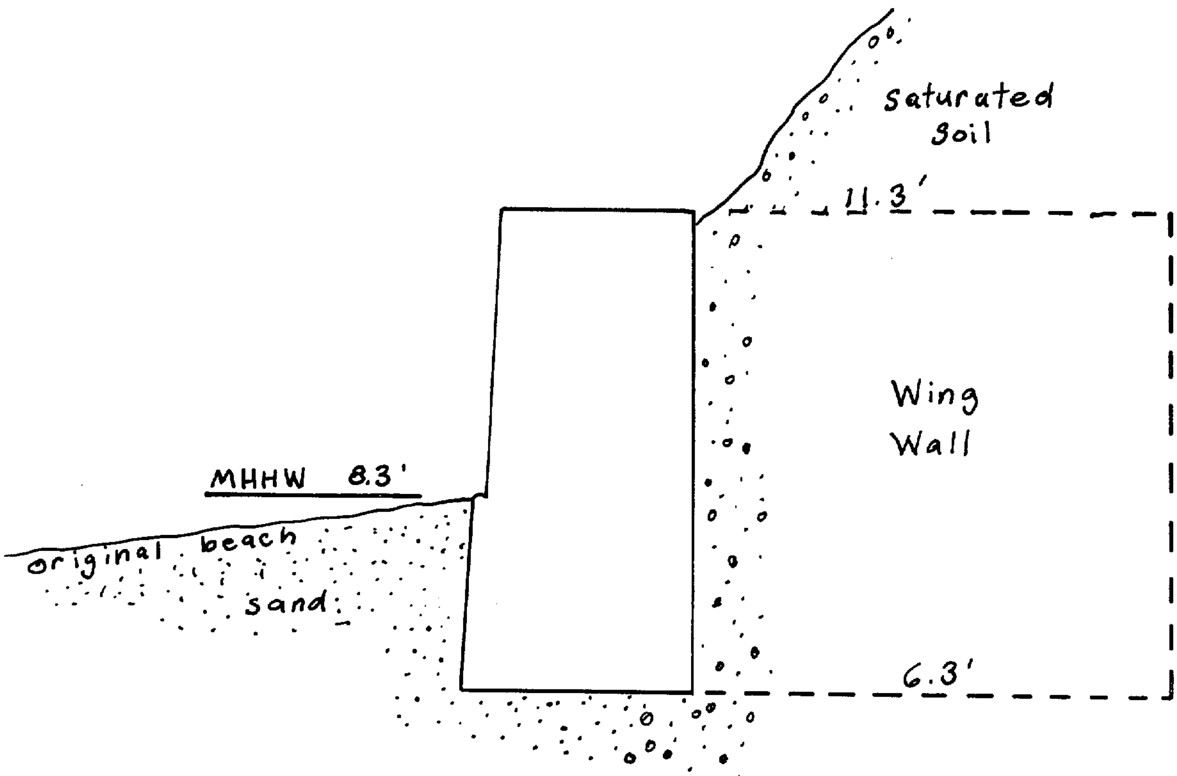
   d. Beach Material: Sand and small gravel

   e. Beach Slope: 1:8

5. Coastal Hydraulics

This site is exposed to wave attack primarily from the north. The net transport of beach material is from the northwest to the southeast, with eroding bluffs approximately 1/4 mile updrift of the site. Erosion of the beach appears to be a fairly slow process with the beach profile lowering at a rate of between 0.05 and 0.1 per year. This erosion contributed to, but does not appear to be, directly responsible for failure of this bulkhead. The primary cause for failure was probably the slumping of the bank which forced the bulkhead outward from behind.

6. Construction Details



This bulkhead, as originally constructed was adequately strong to resist the wave attack experienced at this site. However, the bulkhead was not a satisfactory bank retaining device. Lack of weep holes for drainage along the base of the bulkhead, compounded the bluff saturation problem. No tie-backs were incorporated in the original structure and the bulkhead had no rock toe protection. If toe protection or beach nourishment had been incorporated in the bulkhead maintenance, the 1-1/2-foot of toe scour which had occurred over the last 20 years could have been reduced. However, as discussed previously, toe scour is probably only a partial contributor to the problem. As constructed, the top elevation of this bulkhead was marginal. During extreme tides, there was virtually no freeboard and any additional wave action probably caused overtopping, adding to the bluff saturation problem.

7. Prognosis

In this case, the lack of bank stabilization appears to be the primary cause of the bulkhead failure. If no solution is found for the bank foundation problem, the undestroyed portions of the bulkhead will probably fail in the near future. With no toe protection, the bank would be exposed to wave action, and the erosion rate could increase dramatically.

8. Possible Improvements

Solving the bank foundation problem could help to slow the rate of erosion at this site. Bank stabilization procedures could include resloping to a more stable angle, dewatering, and revegetation. In addition, a new means of protecting the bank toe should be provided. This could be a new bulkhead, either timber or concrete, or a revetment of some sort. In the event of further bank slumping, a "nonrigid" revetment of rock or gabions might prove less prone to catastrophic failure than a vertical bulkhead of wood or concrete.

1. Structure Number: 4

2. Structure Type: Railroad Tie - vertical bulkhead

3. Location: Fidalgo Island, Skagit County

4. Physical Environment

   a. Maximum Wave Heights: Moderate 2-3 feet

   b. Tides: Tide Range: -4.5 to 15.0
   Mean Higher High Water: 11.2
   Estimated Highest Tide: 15.0

   c. Predominant Littoral Drift Direction: W to E

   d. Beach Material: Gravel

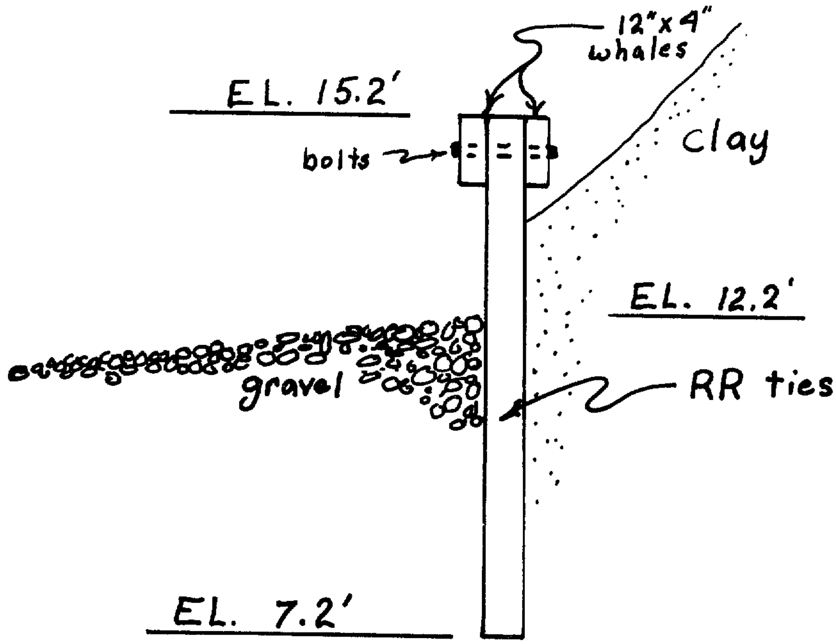
   e. Beach Slope: 1:8

5. Coastal Hydraulics

This site is exposed to wave attack primarily from the south. While the transport of beach material is not pronounced, a small net movement from the west to the east is probable. Since the structure at this site was only recently constructed, no accurate measure of the erosion rate is available. This bulkhead was constructed to protect the bluff toe from wave attack, thus stopping for the time being, the cycle of toe erosion and slumping typical of coastal bluffs.

6. Construction Details

Cost: $2,500 (self-constructed)



This bulkhead is adequately strong to resist the level of wave attack experienced at this site, but the structure is not designed to retain the high bluff behind it. The structure top elevation appears to be adequate, but high tides accompanied by moderate wave action may produce some overtopping. Since no filter material was provided behind the structure, fine material eroding from the bluff may continue to pass through the bulkhead. As of the inspection date, toe protection rock has only been provided along the eastern 25 percent of the structure. This rock is adequately sized but protection of the entire toe should be completed promptly. No tiebacks were included in this design, but the structure is only four feet high and, may be adequately strong to support the back fill behind it. However, a major bluff failure would overturn the bulkhead whether or not tiebacks were used.

7. Prognosis

The useful life of this bulkhead should be at least 15 years, providing the bluff behind the structure is stabilized, and that the toe protection is completed. Should more bulkheads be constructed along the base of the updrift bluff, the beach erosion rate may increase and some corrective measures may have to be taken.

8. Possible Improvements

The bluff behind the bulkhead should be watched carefully. Drainage and revegetation of the bluff should be seriously considered. The western 75 percent of the bulkhead should be provided toe protection as soon as possible, and free-draining gravel and coarse sand should be placed as a filter behind the structure.

SHORE PROTECTION STRUCTURES - ANALYSIS OF DESIGN

1. Structure Number: 5

2. Proposed Structure Type: Concrete - vertical/recurved bulkhead (proposed)

3. Location: Nisqually Reach, Thurston County

Bulkhead Site

4. Physical Environment

   a. Maximum Wage Heights: Moderate 2 feet

   b. Tides: Tide Range: - 4.5 to 17.0
      Mean Higher High Water: 13.4
      Estimated Highest Tide: 17.0

   c. Predominant Littoral Drift Direction: Approximately neutral

   d. Beach Material: Sand and gravel

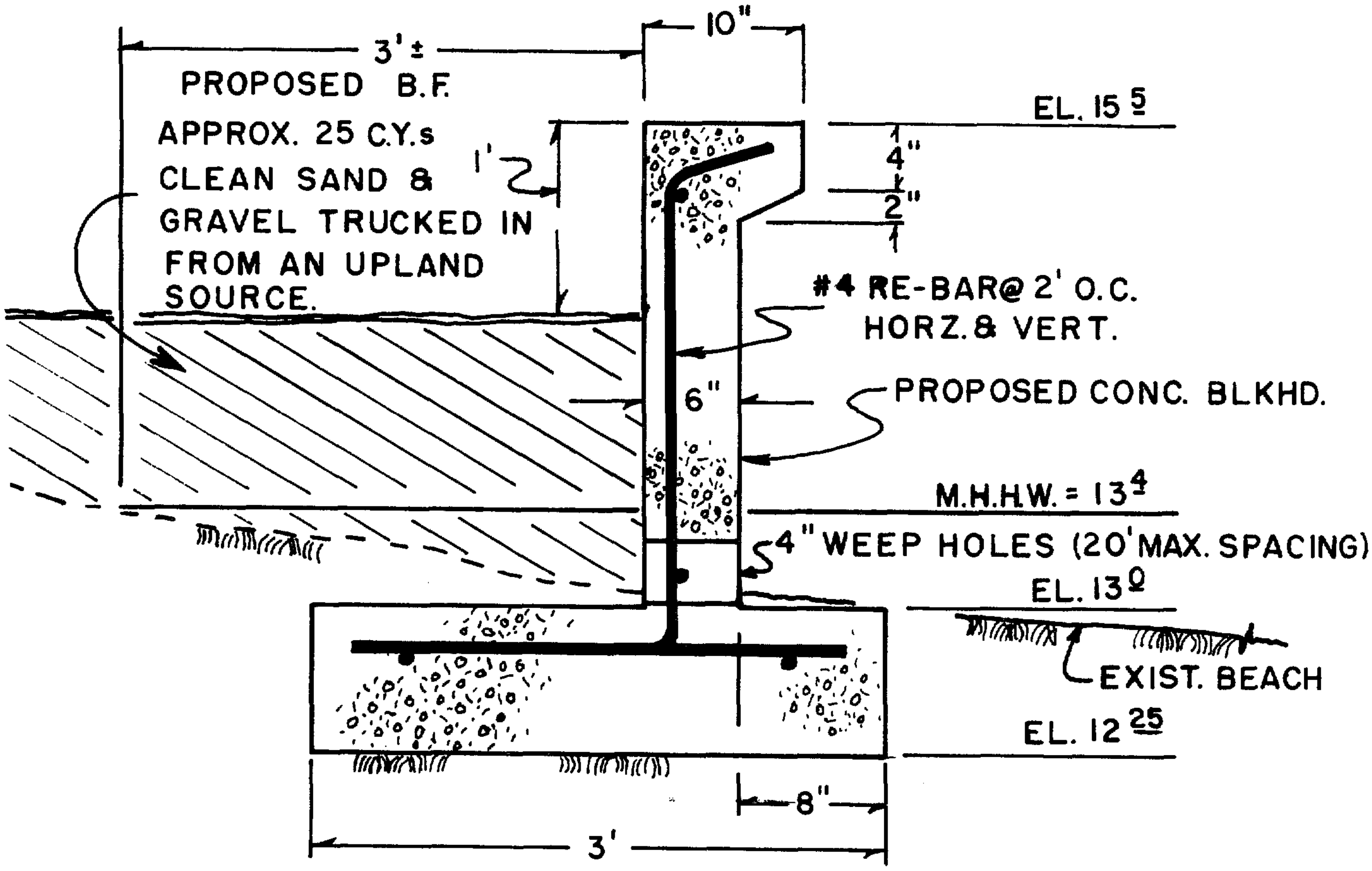
   e. Beach Slope: Approximately 1:8

5. Coastal Hydraulics

This site is evenly exposed to wave action from both the north and south. No net transport of littoral material is obvious. The concave shape of the shoreline creates a fairly protected beach at this site. Offshore wave heights of about three feet are probably reduced to less than 2-1/2 feet before they reach the shoreline, and beach erosion at this site does not appear to be severe.

6. Construction Details

Cost: $7,000 (estimated)



Proposed Design

The proposed bulkhead should be sufficiently strong for the wave climate at this site. However, the indicated bulkhead top elevation of 15.5 feet above mean lower low water (+15.5 mllw) is about 1.5 feet below the maximum estimated tide. At this elevation, the structure would probably be overtopped at least once annually. Since the proposed bulkhead does not completely enclose the backshore area and the foundation is extremely permeable, raising the top elevation by 1.5 feet or more would not insure that the backshore would remain dry. The plans for the proposed work show a backfill behind the bulkhead to an elevation of +14.5 mllw. This elevation probably will be surpassed by several tides each year. No toe protection is shown in the design plans, and without toe protection, the 9-inch deep footing is marginal.

7. Prognosis

This structure will probably do little to protect the backshore property from tidal flooding and could add to the problem by allowing the incoming tide into the backshore area and then retaining the water as the tide recedes. In addition, construction of the bulkhead may cause some increased erosion of the beach in the vicinity of the structure toe. The life of the bulkhead could be 20 years or more, depending on the toe scour rate and the degree of maintenance provided.

8. Possible Improvements

To provide protection from tidal flooding, the residence at this site could be raised to an elevation of at least +18 feet mllw. The bulkhead top elevation should be at least +18 feet also. An alternative solution would be to raise the residence, and place a berm of gravel and sand between the residence and the mhhw line. This berm should extend to an elevation of about 19 feet mllw and would serve as a debris barrier during extreme tides.

SHORE PROTECTION STRUCTURES - ANALYSIS OF DESIGN

1. Structure Number: 6

2. Structure Type: Concrete - vertical/recurved bulkhead (proposed)

3. Location: Dana Passage, Thurston County

Bulkhead Site

4. Physical Environment

   a. Maximum Wave Heights: Mild: less than 2 feet

   b. Tides: Extreme Tide Range: -4.5 to 17.5
      Mean Higher High Water: 14.4
      Estimated Highest Tide: 17.5

   c. Predominant Littoral Drift Direction: Approximately Neutral

   d. Beach Material: Sand, gravel, and cobbles

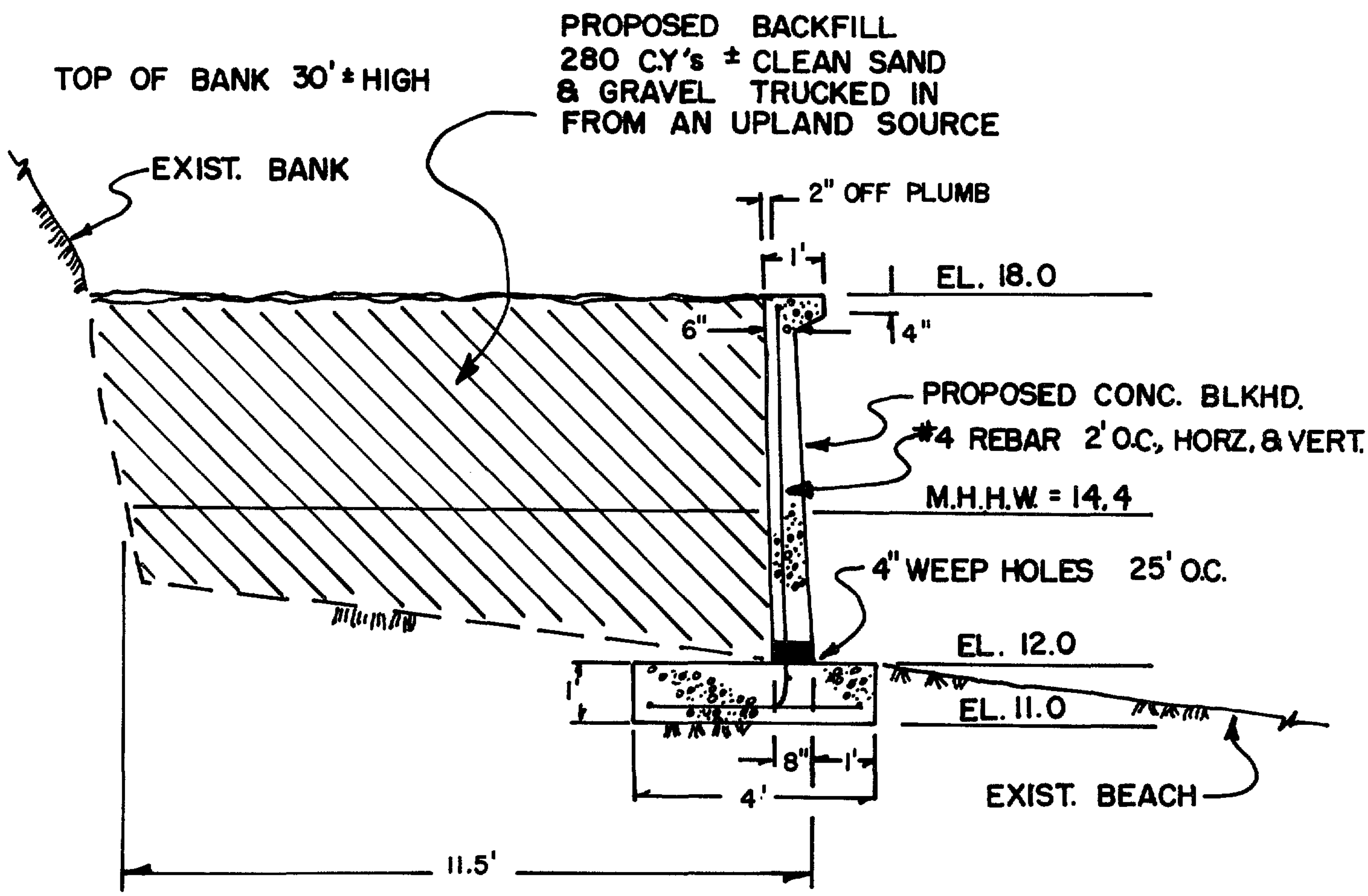
e. Bluff Geology: The material at this site ranges from clayey silt exposed on the upper beach to 10 feet of silty sand in the lower bank, grading into a more silt free sand above. The lower bank has been severely undercut by wave action in places. The bank is failing both as relatively small scale debris slides and as caving slabs of cohesive sand

5. Coastal Hydraulics

This site is exposed to wave attack primarily from the north. Relatively short fetches limit significant wave heights to less than two feet. Because the shoreline is oriented perpendicular to the predominant direction of wave approach, there is little net transport of littoral material along this beach. Erosion problems here are probably a result of ground water activity causing the bluff of silt and clay to slump. Wave action then carries the material from the bluff toe.

6. Construction Details

Cost: $7,000 (estimated)



Proposed Design

The proposed bulkhead is sufficiently strong to resist waves which attack this site. The purpose of the bulkhead would be to retain the backfill material and additional bluff material which slumps onto the backfill and to prevent toe erosion. The top elevation of the bulkhead is satisfactory, but a footing depth of one foot may be marginal, particularly with no toe protection. No tiebacks are shown in the design, and with six feet of fill behind the structure, tiebacks may be desirable. The surface layer of beach material appears to be underlain by a clay-like material and attention should be paid to preparing a foundation for the bulkhead.

7. Implications of the Geology to Shore Defense:

Two aspects of the geology and active geologic processes at this site relate to the design of any shore protection structures. A bulkhead could easily slide on the surface of the very hard impermeable silt underlying the gravels. Thus, it would need to be well "keyed" the silt surface but without disturbing it. Drainage would have to be carefully provided for as there would have to be no underflow. Secondly, superficial bank failure will continue but at a slower rate, even after construction. Thus, the bulkhead will need to perform some retaining wall functions as well as providing wave protection.

8. Prognosis

The life of this structure will depend primarily on its ability to resist overturning due to soil pressure. A high saturated bluff of clay and silt, and a clay-like foundation, will make the construction of a durable structure extremely difficult. Even if the bulkhead can resist overturning, the bluff will probably continue to slump until it reaches a stable slope.

9. Possible Improvements and Alternatives

The proposed desing may have a better chance of success if the following measures are incorporated:

a. Use tiebacks

b. Increase footing depth

c. Provide toe protection

d. Provide an adequate foundation

A riprap revetment is an alternative design which, if economically feasible, would be more flexible and might be less prone to catastrophic failure. Here again, foundation preparation would be critical. Another solution, if permits could be obtained, would be to construct an artificial beach of gravel and coarse sand. If graded to a 1:6 slope, such a beach fill would require about six cubic yards of material per foot of beach, in addition to the proposed backfill. This type of protection would not be damaged by additional slumping of the bluff, and with periodic replenishment, would protect the bluff from wave action.

SHORE PROTECTION STRUCTURES - ANALYSIS OF DESIGN

1. Structure Number: 7

2. Structure Type: None proposed as yet

3. Location: Tulalip Shores, Snohomish County

Erosion Site

4. Physical Environment

   a. Maximum Wave Heights: Severe, 3-4 feet

   b. Tides: Extreme Tide Range: -4.5 to 14.5
      Mean Higher High Water: 11.2
      Estimated Highest Tide: 14.5

   c. Predominant Littoral Drift Direction: Northwest

   d. Beach Material: Sand and gravel

   e. Beach Slope: 1:10

   f. Bluff Geology: The geology in this general area consises of a gray silt making up the lower bluff, with the overlying material largely sand. The upper surface of the silt unit varies from 10 to 50 feet above high tide. The site in question appears to be a low place in the surface of this water-perching silt. The resulting concentration of groundwater was probably responsible for what appears to be an ancient landslide.

5. Coastal Hydraulics

This site is exposed to heavy wave attack from the south. An effective fetch of about 6 miles allows the generation of waves in excess of 5 feet high. The relatively shallow beach probably causes the highest waves to break offshore, and waves striking the bluff toe should be limited to 3 to 4 feet under most conditions. The predominance of southerly waves causes the net transport of littoral material to be toward the northwest. Erosion problems at this site appear to be serious and seem to result from ground water activity in the bluff combined with wave action attacking the bluff toe. The bluff is over 100 feet high and appears to be composed of silt, clay, and sand. Material from the bluff is deposited at the bluff toe, then removed by wave action.

6. Construction Details

No bulkhead has been constructed recently at this site, and no design has been proposed.

7. Implications of Geology to Erosion Defense

A bulkhead at this site may need special attention to its foundation design as the disturbed slide materials may well extend into the upper beach. As ancient landslides may reactivitate, every effort should be made to prevent groundwater buildup within the slide mass as well as the bank. Prevention of reactivation through drainage control will probably be much more effective and cheaper than a retaining structure.

8. Prognosis

Based on the location of old bulkhead remains on the beach fronting the bluff, the bluff is eroding at an average rate of about 1/2 foot per year. With no remedial action, this erosion rate will probably continue into the foreseeable future.

9. Possible Improvements and Alternatives

Due to the magnitude of the erosion problem at this site, relocation of the bluff top residences should be given serious consideration. However, the erosion process might be slowed by protecting the bluff toe with a riprap revetment or some other structure which would not be completely destroyed by future slumping of the bluff.

EROSION ABATEMENT ADVICE

The abatement of an erosion problem can be achieved only if the causes are clearly understood. A variety of processes cause the retreat of beaches and shore bluffs, which are not obvious to an untrained person. It is best to seek the opinion of a professional who can pinpoint the causes, and in the longrun save the property owner time and money.

There are some basic procedures that should be followed to prolong the life and effectiveness of any erosion abatement method chosen. A discussion of the various techniques, their advantages and disadvantages follows.

Construction Setback

The best way to avoid a hazard is to move away from it. Cities and counties bordering the marine waters of Washington state have shoreline construction setback requirements established in their shoreline management programs. These agencies must be consulted prior to construction.

The cost and benefits of moving a home back from the shoreline or bluff edge should be considered. Many times this cost compares favorably with other protection methods and might provide protection longer than many structural solutions.

Advantages:

Reduces the threat of structure destruction.

Allows shoreline processes to operate naturally.

No impacts to neighboring properties.

Preserves recreational and aestetical value of the beach.

Can be accomplished by the individual through contract with a housemover.

Minimum of permit problems.

Disadvantages:

Does not stop erosion.

Area must be available for relocation.

May reduce arc of shore view from relocated position.

Special skills and equipment required.

Vegetation

Vegetation helps to shelter and bind the soil and substrate from erosion. Removal without replanting is poor practice, and bare spots should be planted. Some varieties of plants are better than others for bank stabilization. A local nursery operator, county extension agent or local office of the Soil Conservation Service should be consulted. If removal of large trees and other large plants is necessary, the roots should be left in the soil to help maintain stability.

Successive plantings first with grasses or ivy, then with shrubs and trees will help to shelter and bind the soil and substrate for maximum protection.

Advantages:

Shelters and bind the soil and substrate.

Reduces soil creep and rain erosion.

Self maintained and renewable protection.

Disadvantages:

Does not stop erosion at bluff toe.

Growing vegetation may reduce views.

Vegetation may interfere with access.

Has little effect on deep seated slides.

Beach Nourishment

A viable alternative to saving an eroding beach is to artificially restore it by adding sediment of a similar type. This technique is not always practical or possible. Major obstacles to many beach nourishment proposals are the acquisition of large quantities of sand or gravel of suitable type and size and the transportation of this material to the beach.

The cost of sand or gravel for beach nourishment depends largely upon the source of the material and the method and distance of transport. A total cost for loading, hauling and spreading at an approximate cost of $2.50 to $3.00 per cu. yd. A rule-of-thumb estimates that for each one foot of visible recession of the shoreline, the beach has lost two cubic yards per shoreline foot. Thus, a 100 ft. shoreline that has eroded ten feet would require approximately 2000 cubic yards material.

Advantages:

Most effective method of dissipating wave energy.

The beach after treatment remains suitable for recreation and attractive.

Nourishment does not adversely effect downstream beaches.

Disadvantages:

Beach will likely require additional material.

Cost and accessibility of "borrow" material may be prohibitive.

Bulkheads and Seawalls

These structures are similar. They are vertical walls made of concrete or wood placed on a beach to rebuff wave attack and retain the land behind the structure. These structures are subject to various hydraulic forces that must be accounted for in their design and strength of materials.

Seawalls and bulkheads should be constructed sufficiently high to prevent wave overtopping during extreme tides and footings should be dug deep into the beach to avert their exposure. In general, the maximum depth of expected scour is roughly equal to the highest breaking waves at the site. Maximum storm waves two feet high prescribe a footing depth of two feet. It is advisiable to go beyond the minimum if economically and physically possible. Some wave scour will occur; however, large rocks placed on the beach in front of the structure will help to reduce the erosive impacts of wave scour.

A seawall or bulkhead protects only the land behind it or the beach in front of them. These structures provide no protection to either up or downcoast areas. The structures may be placed just at the site of erosion or along the entire length of the property. The ends should be joined to neighboring structures. Where none exist, wing walls or tie-ins to the adjacent land must be provided to prevent flanking and possible progressive failure from the ends.

Accumulating water and soil pressures soon build behind bulkheads and seawalls. Drainage must be provided to allow groundwater to escape from the landward side of the wall. This can be facilitated by backfilling with gravel and by making frequent openings (weep holes) through the wall near the level of the beach.

Additional strength can be given to the structure through the use of tie backs. Tie backs anchor the upper part of the wall with steel cables to logs or other large materials deeply embedded into the beach or shore bluff (Figure 3). These structures are rarely capable of, or designed for, stopping deep seated landslide activity. They can help prevent reactivation of former slides however, by preventing the erosion.

Advantages:

Shields the land from wave scour and undercutting.

Low maintenance if properly constructed.

Disadvantages:

Limits beauty, access and use of beach.

Incompatible with conditions for some forms of natural plant and animal life.

Complex engineering design.

Construction requires special equipment.

Subject to failure from use of improper materials or design flaws.

Costs:

The costs of seawalls and bulkheads vary considerably. The price is dependent upon the type of materials used, the special equipment required, and the type of labor. Generally, wooden installations range from $30 to $50 per linear foot, and concrete $60 or more per linear foot.

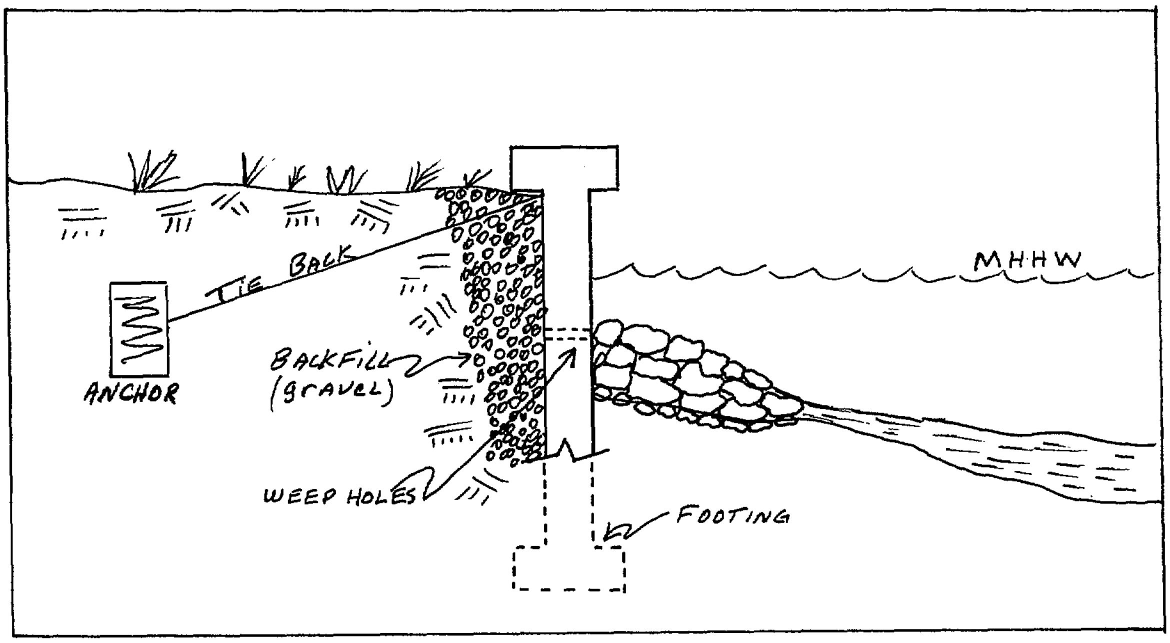


Figure 3

Revetments

Revetments are among the least expensive type of protection. They consist of armor facing of blocks, rocks, or other hard material placed like a blanket on the natural sloping shore. The revetement functions as a wave energy dissipator. Since the joints between the rocks in the revetment facing are usually open and not watertight, special care must be taken to prevent scour of supporting shore material as the returning splash and surface runoff flows back to the sea. Twelve to eighteen inches of gravel or woven filter mat should be placed between the natural soil and the revetment. The filter is designed to retain the solids as water flows through (Figure 4).

Advantages:

Relatively least expensive (armor) protection.

Constructed of individual units, able to accommodate some settlement and replacement.

Provides a sloping surface and may accommodate some forms of intertidal marine line.

Disadvantages:

The stability of the light armor facing is dependent upon the strength underlying base material.

If the filter fails, the underlying material is easily lost through open joints.

Adversely impact the scenic and recreation quality of the beach.

Costs:

Revetments vary significantly in cost. Most of the cost is involved in the transportation and placement of the material. Prices can

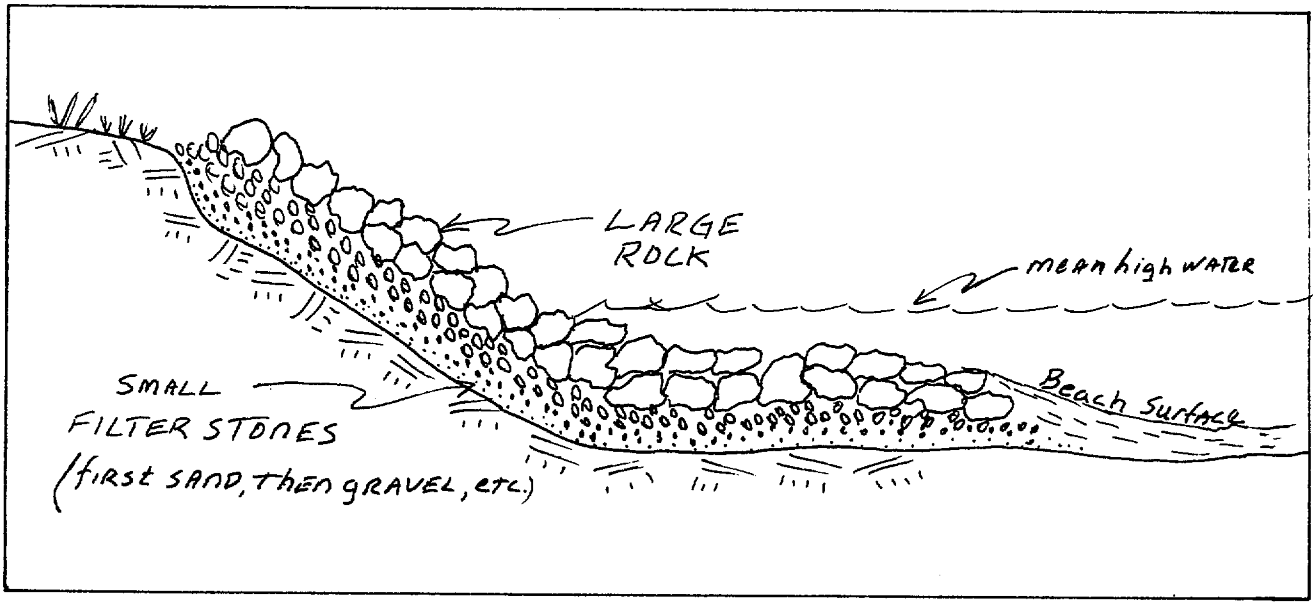

LARGE ROCK
mean high WATER
Beach Surface
SMALL FILTER STONES
(first SAND, Then GRAVEL, etc.)

Figure 4

range from $30 to $80 per linear foot.

Groins

Groins are long, low finger-like structures that jut out perpendicular to the shore and dissipate or deflect the erosive energy of longshore currents and waves. Groins may be used to either maintain a beach with its present profile or build up a beach by trapping littoral sediments passing along in the surf. The usual result is a buildup of sediment on the updrift side and consequent erosion on the downdrift side. While intended to protect the shore, they often cause shore erosion, especially downdrift from the structure. Many law suits have been initiated by property owners claiming increased erosion damage resulting from the installation of a groin. Groins generally are not necessary for erosion abatement in Puget Sound, and their use except in very special circumstances is ill-advised.

Advantages:

Quickly trap and impound longshore moving sediments.

Buildup the beach on the updrift side.

Disadvantages:

Shoreline downdrift will experience rapid erosion.

Unsuitable in areas of low littoral sediment transport.

Opens the property owner to legal liabilities to damages suffered by downdrift property owners.

Costs:

Small groins can be constructed of wood or rock. The former can be constructed inexpensively but may require the use of a backhoe or pile driver. A wooden groin may range in price from $10 to $25 per

Summary of Erosion Abatement Techniques

	Construction Setback	Vegetation	Beach Nourishment	Bulkhead Seawall	Revetment	Groin
ADVANTAGES	Reduces threat of destruction	Shelters and binds soil and substrate	After use beach suitable for use	Shield the land from wave attack	Least expensive	Quick trap of beach sediment
	Allows natural shore processes to operate	Reduces soil creep and rain/gulley wash	Does not impact down-stream beaches	Low main-tenance	Individual units allows settlement & replacement	Builds beach on updrift side
	No impact on beach life	No impact on beach life				
DISADVANTAGES	Does not stop erosion	Does not halt erosion	Does not stop erosion	Limits access & recreational use of beach and scenic view	Subject to settling	Downdrift beaches erode
	Area must be available for relocation	Vegetation may reduce views	Cost and ac-cessibility of borrow material	Complex design	Underlying ma-terial lost through joints	Unsuitable in low littoral transport areas
	May reduce views	Reduces access	Impacts beach life	Special equipment needed	Impacts beach life	Legal problems may result
	Special moving skills			Subject to failure if improperly designed	Limits recre-ational use of beach and sce-nic value	Impacts beach life
				Impacts beach life		Limits recreational use of beach
COSTS	\$3.00 to \$5.00 per sq. ft.	minor	\$2.50 to \$3.00 cu. yd.	wood: \$30 to \$50 ln ft concrete: \$60 to \$80 ln ft	\$30 to \$80 ln ft	wood: \$10 to \$25 ln ft concrete:\$30 to \$80 ln ft

linear foot, however, the wood will require relatively frequent maintenance. The costs of a rock groin is dependent upon the accessibility of large rock. Costs may range from $30. to $80. per linear foot.

CONCLUSIONS AND RECOMMENDATIONS

It should be obvious to the reader that the shore is a dynamic environment and a basic incompatibility emerges with the installation of rigid erosion protection structures in this "fluid" environment. A variety of structural alternatives have been presented; however, each has advantages and disadvantages that must be considered in light of the physical conditions that prevail at the erosion site. The selection of the most appropriate technique must be based on an assessment of physical conditions, costs, and accessibility (fig. 5).

Figure 5

Physical Conditions	Cost	Accessibility
Wave heights Wave direction Tidal heights Littoral drift Beach & bluff geology Water run-off (surface & ground)	Materials Installation (machinery & labor)	Materials Installation (machinery)

Physical conditions vary greatly around Puget Sound. It is therefore very difficult to recommend any one erosion protection technique above another without knowing conditions of the site. However, certain generalizations can be made for three general catagories of shore types found in Puget Sound: low beach (no bluff) beach with low bluff (up to 50 feet), and beach with high bluff (greater than 50 feet). Under all circumstances, non-structural alternatives stand alone in reducing erosion with the least disruption of natural shoreline processes. If for reasons of physical conditions or cost non-structural methods are not appropriate, structural techniques may be the only recourse.

Along the relatively few low sand and gravel beaches in Puget Sound, log or railroad tie bulkheads of the type shown in case example (2) appear to be the most effective in terms of cost and service. Installation of a log or railroad tie bulkhead with neeessary footing depth and supports are relatively inexpensive to install and provide some flexibility to long and short term beach changes. Furthermore, repairs are relatively easy to accomplish. Concrete bulkheads are also often used as erosion protection on low beaches. While some do serve well, many are prone to failure or require frequent repair as shallow footings are exposed or tension cracks appear, severely weakening the structure.

The most common physical type of shore found around Puget Sound is the gravel and cobble beach backed by a low bluff. Here it is important to determine the principal cause of erosion which can usually be attributed to one of two events, undermining by storm waves, or weakening of the bluff by ground water saturation. If wave erosion is the principal erosion agent, rip rap or a wooden bulkhead may be installed to check the waves' erosive power. However, in many cases, the erosion results from groundwater saturation of bluff strata causing differential pressures resulting in debris slides and slumps. Breaking waves simply move the fallen debris along the beach. An example of this is shown in case example (6). Under these circumstances, a strong reinforced concrete retaining wall, back-filled with gravel appears to be the best solution to reducing the erosion. Frequent "weep holes" through the wall are necessary to prevent water buildup behind the bulknead.

Lastly, where erosion is occurring to high shore bluffs in excess of 50 feet, as shown in case example (7), the problem is compounded by the large amounts of debris that fall upon the beach. Any type of retaining structure would have to be of massive dimensions beyond the financial capabilities of most individuals. A few actions may be taken: (1) relocation of the home a safe distance from the bluff edge; (2) removal of groundwater (dewatering) by pumps or the interception of flow; and (3) the placement of rip rap at the toe of the bluff to help reduce the force of breaking waves. All three actions should be taken, but relocation of the home (if possible) should be given the highest priority.

Regardless of the physical conditions of the site the property owner should consider all erosion protection options and discuss them with his local planning or building department representative. They are most familiar with local conditions and are in the position to provide information about the range of alternative actions that are permitted.

PERMITS AND ASSISTANCE

Permits

The property owner faced with an erosion problem should first consult with his local planning or building and codes department before taking any action. These agencies participate in Washington's Shoreline Management Program which deals with development on marine and freshwater shorelines of the state. The local agency can advise the property owner of site information, possible abatement techniques and inform him of legal limitations.

In most cases it is in the property owners best interests to call a professional geologist or engineer to review the problem. Professional advice, in the long run, will save time and money. Perhaps the problem can be solved by employing a non-structural technique. However, if structural abatement is necessary, appropriate permits must be acquired prior to installation.

The U.S. Army Corps of Engineers is designated by the U.S. Congress the authority of regulating all dredging, filling, bulkhead and pier construction in the "navigable waters of the U.S." by The Rivers and Harbors Act of 1899 (USC 404 Sec. 10). Along the Pacific Coast, "navigable waters of the U.S." are channelward (seaward) of Mean Higher High Water. Thus, the type of permits necessary for the construction of an erosion defense structure depends on the location of the proposed structure in relation to the Mean Higher High Water (MHHW) on the beach. If the proposed structure is landward of Mean Higher High Water, permit approval need only be obtained from the local (city or county) planning or building and codes department. If, however, the proposed structure is seaward of Mean Higher High Water, approval must be obtained from the local agency, Department of Fisheries (state) and the U.S. Army Corps of Engineers (federal).

Accurate definition of the Mean Higher High Water mark requires a survey. However, one can estimate the location through the use of tide tables. Another approach is to assume the lowest limit of land vegetation growth demarcates Mean Higher High Water. However, it should be noted that some local jurisdictions do not allow the installation of defense works beyond the toe of the bluff, or on the backshore berm of a beach.

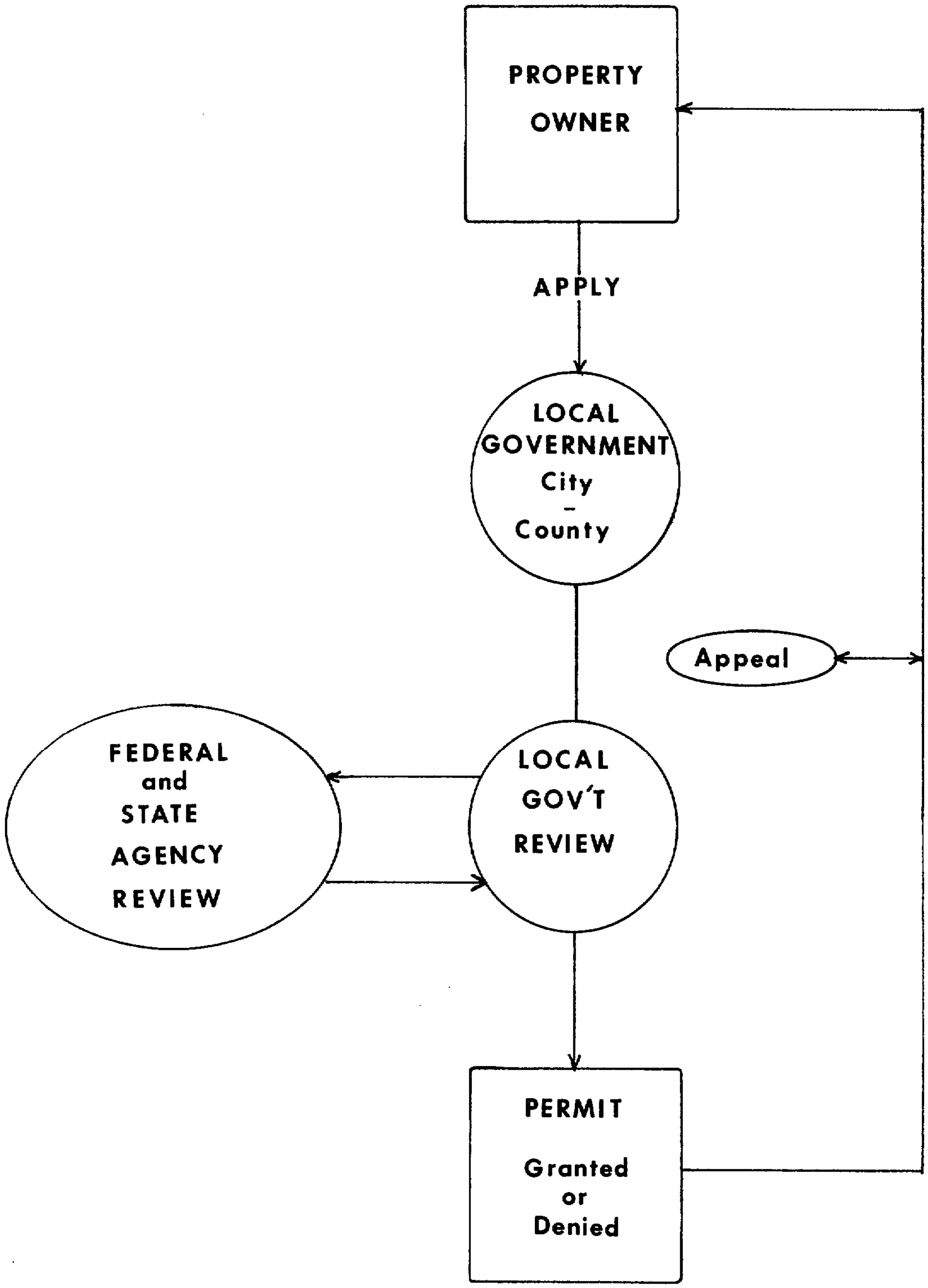
Assistance

Local Government. A concerned property owner is probably not the first or only person experiencing an erosion problem in his local area. The initial step is to discuss the problem with the local city or county planning or engineering office. They have designated authority over development along the shoreline of the local jurisdiction through Washington's Shoreline Management Program. Furthermore, they are familiar with the area and must be contacted to obtain appropriate installation permits. While these offices may not be able to provide specific remedies to an individual erosion problem, they will explain the range of actions that are legally permitted. Additionally, they may be able to direct someone to professionals nearby for area specific information and assistance.

State Government. Three different state agencies may be of assistance to the citizen with a beach erosion problem. They are the

Department of Ecology, Shorelands Division; Department of Natural Resources, Division of Geology and Earth Resources; and the Department of Fisheries. These Departments are sources of legal, geological and biological information relating to the shorelines of the state. However, they will generally not provide direct assistance to property owners.

Federal Government. The U.S. Army Corps of Engineers is the lead federal agency dealing with public works projects in and around navigable waters of the United States. This agency is responsible for major harbor improvements and erosion abatement projects. They are designated by law to act only in behalf of the U.S. public at large and not for an individual citizen. However, general information dealing with erosion problems and permit requirements is available through the Seattle District Office.


PROPERTY
OWNER
APPLY
LOCAL
GOVERNMENT
City
-
County
Appeal
FEDERAL
and
STATE
AGENCY
REVIEW
LOCAL
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REVIEW
PERMIT
Granted
or
Denied

BEACH AND BLUFF EROSION:
Signs of A Problem

The understanding of bluff and beach processes is academic unless the knowledge can be applied in a functional way. Early recognition of erosion before it progresses into a severe problem is important to its control. The following gives some of the signs of beach and bluff erosion. Be on the lookout for these signs and, if possible, study small changes in the nature of your shore bluff or beach over time using photographs or other means of comparison.

SHORE BLUFF

Type of Geologic Material

- Hard Rock
- Homogenous rock and gravel embedded in sand and silt
- Layers of gravels, sands, silts, and clays

Evidence of Instability

- Cracks in the soil parallel to bluff edge
- Bare exposures of soil (slump scars)
- Trees bend or tilted downslope
- Trees with exposed roots at bluff edge
- Masses or recently fallen debris (soil, rock, & vegetation) at base of the bluff
- Notching at the base of the bluff from wave scour
- Active water flow over the face of the bluff
- Springs emitting water from within the bluff
- Water slowly "weeping" from strata within the bluff

BEACH

- Obvious longterm recession or lowering of the beach relative to some "fixed" object *
- Longterm change in the size of beach sediment from smaller to larger particle sizes

- Undercutting and removal of upland vegetation or beach grasses

MAN MADE STRUCTURE

- Bulkheads or other erosion defense structures on neighboring beaches
- Groins on neighboring beaches "trapping" beach sediment
- Cracking or undercutting (exposed footings) of existing erosion defense structures

* Study your beach relative to some natural or manmade object such as a boulder on the beach or piling that is fixed or photograph the same part of your beach each year in mid or late summer and compare with older photographs

GLOSSARY OF TERMS

Backshore: The zone of the beach profile extending landward from the sloping foreshore to the point of development of vegetation or a change in physiography (bluff or dunes).

Beach: The zone of unconsolidated sediment extending shoreward from near low tide line to some physiographic change such as a bluff or dune field or to a point where permanent vegetation is established.

Beach Nourishment: The process of replenishing a beach. It may be brought about naturally, or artificially by the deposition of materials from another source.

Beach Profile: The intersection of the ground surface with a vertical plane; may extend from the top of the dune line to the seaward limit of sand movement.

Bluff: A high steep bank at the seaward edge of the coast.

Debris Slide: An unconsolidated mixture of fallen bluff material, vegetation, and water.

Dewatering: The process of removing ground water by pumping or injecting pipes to intercept flow.

Fetch: The horizontal distance over which wind generates waves.

Footings: An enlargement at the lower end of a wall or column to distribute the load.

Groin: A shore erosion protection structure built perpendicular to the shoreline to trap littoral drift.

Longshore Current: The littoral current in the breaker zone moving essentially parallel to the shore, generated by waves breaking at an angle to the shore.

Littoral Transport: The movement of littoral drift in the littoral zone by waves and currents.

Littoral Drift: The sedimentary material moved in the littoral zone under the influence of waves and currents.

Mean Higher High Water: The average height of the higher high water over a 19 year period.

Nearshore: An indefinite zone extending seaward from the shoreline to just beyond the breaker zone.

Offshore: The comparatively flat portion of the beach extending seaward from beyond the breaker zone to the continental shelf.

Revetment: A facing of stone or concrete built to protect a bluff or bank against wave scour or currents.

Rip Rap: A layer or facing of stones randomly placed to prevent erosion of a beach or bluff face.

Seawall: A structure separating land and water areas, primarily designed to prevent erosion due to wave action.

Setback: A minimum construction limit near the shore of bluff edge to help reduce the immediate and future threat of erosion damage.

Slump: Movement of earth down slope along internal slip surfaces, generally concave upward.